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LORD RAYLEIGH'S "SOUND."

The Theory of Sound. By J. W. Strutt, Baron Rayleigh, Sc.D., F.R.S. Second edition, revised and enlarged. Two volumes. Pp. xiv + 480, and xvi + 504. (London: Macmillan and Co., 1894 and 1896.)

IT was neither to be expected nor to be desired that any alteration of the general plan of Lord Rayleigh's "Sound" should be introduced in a new edition. A few errors have been detected and corrected (they are very few indeed), and the book has been considerably enlarged; but the characteristic features of the new portions are those of the old, and our admiration is again aroused by the skilful interweaving of theory and experiment, each supporting and adorning the other.

We are grateful, too, that there is a continuance of the help which we have received from the author in "clearing our minds of cant," or rather of that unquestioning employment of conventional explanations which is its equivalent in physical science. For example, many would even now be contentedly repeating the ordinary text-book theory of the maintenance of vibrations in an electric bell had he not awakened them to the knowledge that it was wholly beside the mark; and the statement that "a simple vibration involves *infinite* continuance, and does not admit of variations of phase or amplitude" should be very useful to many more.

The first important addition is an investigation of the resultant of a large number of vibrations whose phases are accidentally distributed. An expression is found for the probability of a resultant intensity of any specified magnitude, and the mean intensity is shown to be the sum of the intensities of the components.

Under the head of intermittent vibrations, the difference between intermittence artificially imposed upon a simple vibration and the intermittence of beats is pointed out and employed to explain some experimental results obtained by Prof. A. M. Mayer.

A section is added dealing with unstable systems with one degree of freedom, and we are reminded that the possibility of periodic motion under the operation of impressed periodic force is no proof of stability.

The maintenance of vibrations is then discussed, and it is shown that if impulses are given to a vibrating system whenever it passes through its equilibrium position their effect is mainly upon the amplitude and the period is sensibly unaltered; while if they are given at the moments when the system is at rest the effect is mainly upon the period, the vibrations being neither encouraged nor discouraged. An investigation is also given of the theory of the maintenance of vibrations by a periodic force whose frequency is double that of the maintained system, as in one form of Melde's well-known experiment and in the crispations of a liquid observed by Faraday.

Next we come to a description of some of the principal methods for the accurate determination of absolute pitch, including, of course, the author's excellent comparison of a fork with a clock pendulum by the use of the phonic wheel. An account of this instrument has been given earlier in the book, and its use with a counting apparatus certainly brings a fairly good determination within the reach of experimentalists of very moderate skill. Another interesting method which is described is that of counting the two sets of beats of overtones which are heard when two notes whose interval is an equal temperament-whole tone are sounded on a harmonium. The method depends, of course, on the fact that in *maintained* vibrations the frequencies of overtones must be accurately multiples of that of the fundamental. The necessity of this correspondence is proved later, but a hint of it might have been given here with advantage to the student; for in acoustics, as in other matters, the progress of the human mind is from the vulgar credulity of accepting all overtones as accurately harmonic through the vulgar incredulity of doubting whether any can be so.

In the general treatment of vibrating systems an investigation of the effects of imposed constraints upon the periods is given, also the theorems of Routh relating to the roots of the equation defining the periods, with an extension to unstable systems; a section dealing with the reaction upon the driving-point of a system thrown into forced vibration is also added. Under the head of transverse vibrations of strings the propagation of progressive waves along a string whose mass is supposed to be concentrated at equidistant points is considered, and it is shown that there will be no such propagation if the frequency is above a certain critical value. The reflection of waves at the junction of two strings is treated, also reflection produced by gradual change of density, and it is shown how the analogue of dispersion in optics is introduced if the string is considered to possess finite stiffness, and that in this case the ordinary formula for the intensity of the reflection must be modified. Reflection at a junction is also discussed in the case of longitudinal vibrations of bars, and the weakness of the transmitted intensity when the change of velocity at the junction is considerable is pointed out.

A summary is given of the experiments of Elsas on forced vibrations of membranes, and the march of the nodal lines with varying frequency is described. In the chapter on vibrations of plates an account is given of the author's interesting observations on the notes of bells, and his ingenious method of obtaining the nodal lines corresponding to each note by utilising the beats produced by asymmetry.

The first volume ends with two new chapters, one on the vibrations of thin cylindrical and spherical shells, and one on electrical vibrations. In the latter the theory of oscillatory currents in circuits with capacity and induction is given, and applications to Hughes' induction balance and Wheatstone's bridge are discussed. The concentration of currents of high frequency on the outside of a conductor is also worked out, and the propagation of current waves along cables is treated, justice being done to Heaviside's work on the effect of inductance in diminishing distortion in telephony. The mode of action of the telephone is also discussed, and the author's results as to the minimum audible current are given.

In the chapter on aerial vibrations, which opens the second volume, some interesting phenomena depending upon the second order of small quantities are explained,

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the best known being the striations which are always seen in a Kundt's tube, and which are shown to be due to the tendency of solid particles to arrange themselves in chains perpendicular to the lines of alternating flow. An investigation of reflection at a corrugated surface follows, next comes a description of some experiments on diffraction of sound.

A general account of the mode of maintenance of the vibrations of a flute organ-pipe is then given, and attention is called to the fact that the note of the pipe when sounded is higher than the note to which it would resound, and that the difference increases with the wind pressure. The mutual influence of organ-pipes mounted side by side is considered; it has been shown how this influence militates against the successful application to pipes of Scheibler's method of determining absolute pitch. The maintenance of vibrations by increasing the pressure at a node at a time of maximum pressure and decreasing it at a time of minimum pressure by the introduction and removal of air or of heat is considered. (The student will find it a profitable mental exercise to satisfy himself that this mode of maintenance is consistent with the general principle that the force should be applied when the system passes through its equilibrium position; he may also note the analogy to the maintenance of the oscillations of a galvanometer needle by a small current suitably controlled by a reversing key). If, on the other hand, the moments of the most rapid addition and subtraction of heat are those of most rapid change of pressure, it is shown that the vibration is neither maintained nor damped, the effect being concentrated upon the period. It may be remarked that the passage from Newton's theory of sound to Laplace's, or *vice versâ*, in calculating the pitch of a pipe is a case exactly in point. Among the more important applications of maintenance by heat, singing flames and Rijke's sounding tubes are treated, also the sounds sometimes heard when a bulb has just been blown at the end of a glass tube. The maintained vibration of mercury contained in a U-tube, one end of which is connected with a heated bulb, is a visible example of the latter phenomenon, and the principle has been successfully applied to small hot-air motors. A short account of the conditions of maintenance in reed instruments is also given.

Under the head of fluid friction, Kirchoff's investigation of the effects of viscosity and heat-conduction upon the propagation of sound finds a place, and the behaviour of very narrow tubes towards sound is applied to the question of reflection at a porous wall. The theory of the vortices observed by Dvŏrák in Kundt's tubes is also investigated.

Four new chapters complete the book. The first deals with liquid waves under gravity and cohesion; in it are treated, among other matters, the determinations of surface tension by the measurement of ripples and by observations on the vibrations of a liquid cylinder, the importance of the latter method in permitting the examination of a newly-formed surface being pointed out. The instability of a liquid jet, the behaviour of drops in collision, and the vibrations of detached drops are also considered. The next chapter, on vortex motion, gives an investigation of the instability of stratified motion in a fluid, and its application to the theory of sensitive flames and smoke-jets. Bird-calls and aeolian tones are also shortly treated, some considerations as to pitch being deduced from the principle of dynamical similarity. A brief account of the propagation of vibrations in elastic solids follows, and the last chapter deals with facts and theories of audition. In it the author's experiments on the minimum amplitude of sound waves consistent with audibility are described, a discussion of Ohm's law and its exceptions is given, and, by the application of dynamical principles to the internal vibrators which on Helmholtz's theory form the analysing mechanism of the ear, the bearing of the degree of damping in these vibrators on the origin of dissonance, on the possibility of accurately judging pitch, and on the remarkable results of Kohlrausch as to the exceedingly small total number of vibrations requisite for the appreciation of a definite pitch, is explained. Finally, the conflicting views which have been held as to combinational tones, the perception by the ear of the phase relationship of two tones, and the characteristics of vowel sounds are discussed.

In NATURE of December 12, 1878, Prof. Helmholtz, after suggesting some of the above problems, wrote of the first edition of this book: "Lord Rayleigh certainly deserves the thanks of all physicists and students of physics; he has rendered them a great service by what he has done hitherto. But I believe I am speaking in the name of all of them if I express the hope, that the difficulties of that which yet remains will incite him to crown his work by completing it." This has now been done, but the only voice which could without impertinence utter praise is, alas, silent. L. R. W.

HAWKS AND HAWKING.

Hints on the Management of Hawks (Second Edition); *to which is added Practical Falconry Chapters, Historical and Descriptive.* By J. E. Harting. 8vo. Pp. viii + 268, illustrated. (London: H. Cox, 1898.)

MR. HARTING is such an authority on the art of hawking, and is, furthermore, such an excellent field naturalist, that it was only to be expected his volume on this branch of sport would reach a second edition. But, as the author states in his preface, the additions to the new edition, both as regards letter-press and illustrations, are so extensive as almost to give it a claim to rank as a new work.

From all points of view, management, rearing, training, and use in the field, as well as regards their natural history, Mr. Harting appears to have furnished all that there is to be told concerning hawks and hawking; and if the votaries of this sport are not satisfied with his efforts, they must indeed be hard to please. Some of the most interesting chapters in the volume are those relating to the now obsolete kite-hawking and heron-hawking; the one of which has ceased to exist from the practical extinction of the quarry, and the other from the altered physical conditions of the country. In all portions of his subject the author owes much to the artist, some of the illustrations being really exquisite, especially those from the pencil and brush of Mr. Lodge. What, for instance, can be more striking than the contrast between the figure of

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